Retrospective Study

Clinical Effectiveness, Disability, and Outcomes of Genicular Nerve Ablation for Chronic Knee Pain

Jonathan S. Okereke, BS[1], Alan D. Kaye, MD, PhD[2], Nathan Lien, BS[1], Landyn Johnson, BS[1], Austin S. Thomassenm, BS[1], Sahar Shekoohi, PhD[2], Brian Bernhardt, MD[2], Varsha Allampalli, MD[2], and Azem A. Chami, MD[2]

From: [1]Louisiana State University Health Sciences Center at Shreveport, Shreveport, LA; [2]Department of Anesthesiology, Louisiana State University Health Sciences Center Shreveport, Shreveport, LA

Address Correspondence:
Sahar Shekoohi, PhD
Assistant Professor
Department of Anesthesiology, Louisiana State University Health Sciences Center at Shreveport
Shreveport, LA, 71103
E-mail:
sahar.shekoohi@lsuhs.edu

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Background: Chronic knee (CK) pain has various underlying etiologies with several available therapeutic options that differ in effectiveness, duration, and complication rate. For the past decade, a minimally invasive ablation relying upon genicular radiofrequency has been gaining popularity as a treatment for the condition. To date, however, the literature contains only limited data supporting the effectiveness of this procedure, leading to insurance companies labeling it as "experimental" and denying claims. Benefits described include reduced adverse outcomes and complications, quicker recovery and longer duration of analgesia, and broader scope of applicability when compared to other, traditional treatments.

Objectives: The present investigation focused on genicular radiofrequency ablation (GRFA) and its outcomes, including disability (e.g., stiffness, physical function), pain, and improvement in patients' quality of life.

Study Design: This retrospective, single-center study was conducted to evaluate the safety and effectiveness of GRFAs, plus their associated radiofrequency generators and electrode systems. The equipment consisted of the MultiGen® 2 Radiofrequency Generator (Stryker Corporation) and the RFA Solutions Generator System (Avanos Medical, Inc.).

Methods: Selected patient age ranged between 26 and 92 years, with a mean age of 56.5 years. Thirty-four (34) individuals were enrolled at LSU Health Shreveport, which was the sole investigational site, between March 2021 and 2025. The Stryker SERFAS Energy Platform (Stryker Corporation) was the primary radiofrequency generator selected for genicular ablation (61.9%), with the Avanos RFA Solutions Generator System (Avanos Medical, Inc.) selected for the remaining cases. As for the outcome measures, scores on the visual analog scale (VAS), disability changes measured on the Western Ontario and McMaster Universities Arthritis Index (WOMAC), adverse outcomes, quality of improvement, and ratings recorded in the Quality of Life subsection of the Knee Injury and Osteoarthritis Outcome Score (KOOS) were compared after GRFA.

Results: Mean VAS scores for CK pain intensity decreased significantly, dropping by 3.1 cm from a baseline score of 9.0 cm by the specified end (March 18th, 2025). Furthermore, 66.7% of the patients experienced a 20% or greater improvement in pain, 33.3% of the patients experienced a 40% or greater improvement in pain, and 19.1% of the patients experienced a 60% or greater improvement in pain. Zero (0) procedure-related adverse events or intra- or post-procedural complications occurred during the investigation.

Limitations: The study was retrospective and had no sham operation to determine placebo response. The relatively small sample size (34 total ablations, 21 patients) could have limited the generalizability of the results. Furthermore, the withdrawal rate was 38%, thereby limiting the certainty of the treatment's long-term duration. Results should be considered hypothesis-generating, not confirmatory, but they align well with the growing body of corroborating literature.

Conclusions: The results of this study substantially reinforce GRFA as a safe, effective, and minimally invasive treatment option for patients experiencing CK pain over a 6-month period.

Key words: Radiofrequency ablation, minimally invasive, genicular nerve, chronic knee pain, disability

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Knee pain impairs mobility and functionality and has even been associated with the development of depressive symptoms (1). The condition can be chronic and debilitating, and in the United States alone, knee pain has accounted for over 4 million primary care visits annually, with costs approximating between $5.7 and $15 billion every year (2-3). Chronic knee (CK) pain is such a prevalent issue that 25% of adults are estimated to experience it in their lifetimes (4). Because of its prevalence and high impact on the individual's quality of life, knee pain must be managed and treated carefully.

Managing CK pain is often complicated by the vast number of potential underlying etiologies. Common causes of knee pain include collateral or cruciate ligament sprains, meniscal tears, patellar subluxation, osteoarthritis, and obesity (5,6). These injuries and conditions vary in their severity, including in their impact on overall joint stability and function. In addition, patients often display varied responses to first-line treatment options and frequently require multiple interventions before attaining adequate pain control. Given the ubiquity of knee pain and its often varied manifestations, there is an ever-growing demand for more optimal and effective therapies that work across a broader population.

Initial treatment for knee pain typically includes conservative management, such as non-steroidal anti-inflammatory drugs (NSAIDs), physical therapy, therapeutic exercise, and weight loss. Second-line options may include corticosteroid injections for analgesia or hyaluronic acid injections (viscosupplementation) for lubrication of the knee joint; however, the former type of injection may provide pain relief for only a few weeks, while the latter is typically indicated exclusively in select cases of osteoarthritis, thereby limiting the scope of the injection's applicability (7,8). If these measures fail, patients with refractory pain may consider undergoing more invasive procedures such as total knee arthroplasty (TKA) or total knee replacement. However, outcomes of TKA can be inconsistent, with up to 15-30% of patients continuing to experience pain and stiffness in the knee after surgery (9). Even when TKA is effective, the 11-20.8% complication rate, average recovery time equating to 14 months, and invasive nature of the procedure give pause to patients and clinicians alike, especially patients of advanced age (10-12). Narrowing the scope even further, many patients cannot become surgical candidates due to having comorbidities such as significant heart or pulmonary disease or uncontrolled diabetes and hypertension, additionally reducing existing or available treatment options.

As such, genicular nerve radiofrequency ablation (GRFA) has gained popularity as an alternative, minimally invasive procedure that can help alleviate CK pain. Since 2011, when GRFA was first performed to treat osteoarthritis-related CK pain, the novel technique has gained popularity rapidly, but the procedure remains understudied compared to other treatment modalities in the field (13). GRFAs are performed by first injecting lidocaine into the anterior knee, followed by targeted ablation of the genicular nerves using a radiofrequency generator and electrode system; the goal is to burn selected nerves to prevent the transmission of pain signals that are normally communicated to the brain. The procedure is quick and minimally invasive, and it can preserve motor function, making GRFA a promising alternative (14).

The innervation of the knee joint is complex and can vary among individuals (15). This phenomenon has made localizing pain more difficult; however, the genicular nerves are commonly recognized producers of CK pain. The genicular nerves are sensory nerves that arise from the major peripheral nerves of the lower limb, including the femoral, obturator, common fibular, and tibial nerves. To reiterate, the exact origin of each nerve can vary from one individual to another; nonetheless, it is commonly accepted that there are 4 branches of the genicular nerve, as visualized in Fig. 1: the superior medial (SMGN), superior lateral (SLGN), inferior medial (IMGN), and inferior lateral (ILGN) genicular nerves (15). The fifth genicular nerve, the recurrent peroneal (RPGN), is commonly omitted as a target in clinical practice because of its proximity of the common fibular nerve. GRFAs tend to target the superomedial, superolateral, and inferomedial branches (depicted in Fig. 2), as these 3 nerves innervate specific quadrants of the anterior knee capsule where pain is common. Importantly, the genicular nerves are located safely away from major motor nerves, such as the common and recurrent fibular nerves. This distance makes the genicular nerves favorable to target for effective pain management (13).

Despite the growing use and popularity of GRFA, many insurance companies remain hesitant to cover the cost of the procedure for patients, deeming it "experimental." In fact, before even considering approval for the ablation, many insurance companies mandate 2 preceding trials of combined injections of local anesthetic and steroids into 3 of the 5 genicular nerves, with both trials required to demonstrate over 50%

pain relief. This stipulation delays definitive treatment and prolonging the time the patient spends in pain. As such, further clinical data and evidence are needed to validate the effectiveness of GRFA across patient populations and support its legitimacy as a safe, beneficial, and minimally invasive nonopioid treatment option for CK pain. The present investigation, therefore, evaluated GRFA, assessing its effectiveness, disability-related outcomes (e.g. pain, stiffness, physical function), adverse effects, and associated qualities of life and improvement over a 4-year period.

Methods

Study Design and Objectives

This retrospective, single-center study was conducted to evaluate the safety and effectiveness of GRFAs (using the MultiGen® 2 Radiofrequency Generator [Stryker Corporation] and Avanos RFA Solutions Generator System [Avanos Medical, Inc.]) in the treatment of CK pain, a condition associated most often with osteoarthritis and obesity. The study aimed to contribute to the growing body of scientific literature that recognized and supported radiofrequency ablation (RFA) as a form of knee pain management. Improvements in physical function and stiffness were represented by lower scores on the Western Ontario and McMaster Universities Arthritis Index (WOMAC), while reductions in pain were expressed as lower scores on the visual analog scale (VAS). The quality of improvement survey assessed improvements in sleep, fatigue, anxiety, and depression, while the Quality of Life subsection the Knee Injury and Osteoarthritis Outcome Score (KOOS) assessed patient difficulty with, awareness of, and confidence in the affected knee(s), with lower scores representing worse outcomes.

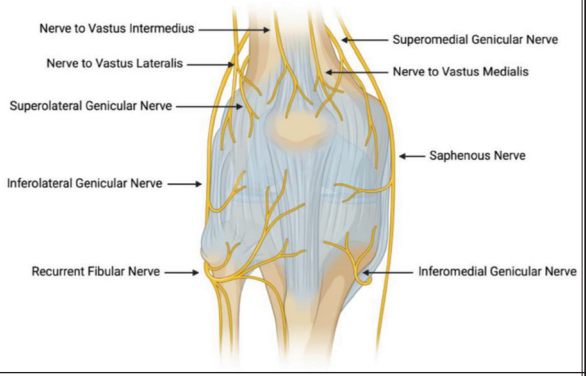


Fig. 1. *Innervation supply to the knee (29).*

Trial Population

Patients were eligible for this study if they had

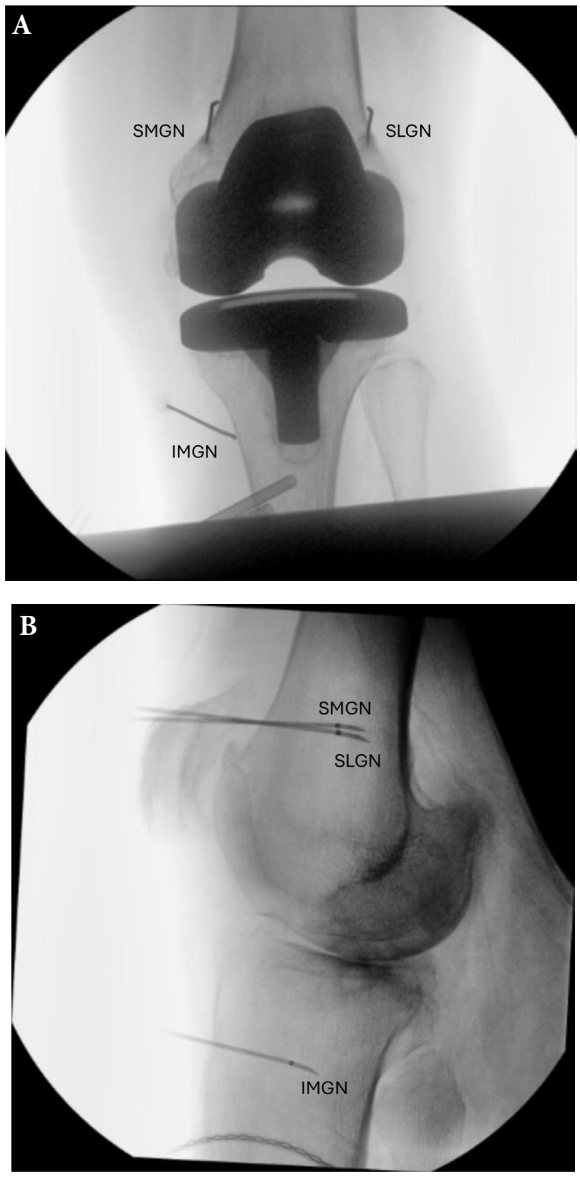


Fig. 2. A) *(AP view): typical fluoroscopic AP view for needle placement in genicular radiofrequency ablations (GRFAs) of the superior medial (SMGN), superior lateral (SLGN), and inferior medial (IMGN) nerves.* B) *(Lateral view): typical fluoroscopic lateral view for needle placement in GRFAs of the SMGN, SLGN, and IMGN.*

been afflicted by CK pain for over 6 months, received a genicular nerve anesthetic injection consisting of dexamethasone and local ropivacaine 0.5% into 3 out of 5 genicular nerves, and experienced over 50% pain relief from said injection. Patients who were pregnant, on an anticoagulation medication, or had an active infection or any other disease process that impacted their candidacy for elective procedures (e.g., history of pulmonary embolism, poorly controlled diabetes, or congestive heart failure) were excluded. Meanwhile, patients with obesity, osteoarthritis, prior knee injuries (e.g., sprains, strains, patellar fractures), tendonitis, fibromyalgia, repetition and overuse injuries, rheumatoid arthritis, or systematic lupus erythematous (SLE) were included and accounted for in the study. The ages of the selected patients ranged between 26 and 92 years, with a mean age of 56.5 years.

Study Procedures

Age, gender, weight, and other relevant data for this study were collected through the Epic Electronic Medical Database, as well as through scores on the voluntary WOMAC, VAS, quality of improvement survey, and Quality of Life subsection of the KOOS questionnaires. WOMAC scores were taken at baseline, one month, 3 months, and 6 months after each patient's procedure. VAS scores were taken prior to each patient's procedure and again by the specified end (March 18th, 2025). Eligible patients were ablated either with the Stryker SERFAS Energy Platform (Stryker Corporation) or Avanos RFA Solutions Generator System (Avanos Medical, Inc.). The RFA device typically operated at 80°C for 60-150 seconds, with an 18-gauge Tuohy needle (Avanos Medical, Inc.) that had an 100-mm lesion tip. The needle was selected and rotated 180° prior to the initiation of another lesion at the 90-second mark. The results presented in this study include all data collected from the complete patient cohort.

Outcome Measures

Primary outcomes were measured by individual improvements in WOMAC and VAS scores from baseline, as well as the absence of ablation-related serious adverse events (SAEs) or of neurological worsening related to contributions from the femoral, obturator, and sciatic nerves. VAS scores (0-10 cm) were measured by the reduction from the percentage of a patient's pre-procedural pain level to the pain level at the specified end. WOMAC scores (0-96 points) were measured by the reduction in pain-level percentage between the aforementioned time periods and categorized as no (0-10), mild (11-30), moderate (31-70), or severe disability (71-96).

Secondary outcomes were measured by the scores on patients' quality of improvement surveys, measuring the individuals' improvements in sleep, fatigue, anxiety, and depression, and the Quality of Life subsection (0-100) on the KOOS, assessing patients' difficulty with, awareness of, and confidence in their affected knee(s).

Safety Outcomes

Safety was measured by the number of SAEs that resulted from the RFA. SAEs included prolonged hospitalization or a life-threatening event caused by the ablation, whether during the procedure itself or in association with the recovery and rehabilitation. Procedure-related SAEs were calculated by dividing the number of events by the total number of ablations (n = 34).

Statistical Methods

Data analysis was conducted to determine statistical significance amongst the primary outcomes. WOMAC and VAS data were inputted into Analysis ToolPack (Microsoft) and computed using the paired t-test analysis. All statistical analyses were performed and completed in September 2025, and all tests were 2-sided with a significance level of 5%, unless otherwise denoted. All other data are reported descriptively as appropriate (e.g., means, proportions, etc.).

Results

Patient Demographics

Patient cohorts can be found in Table 1. Thirty-four (34) individuals were enrolled at LSU Health Shreveport, which was the sole investigational site, between March 2021 and 2025. All 34 patients were ablated, with 21 completing the one-month and the 3-month visits, and 19 completing the 6-month visit. Thirteen (13) patients withdrew from the study after their ablations, with the individuals' specific reasons for study withdrawal included in Table 2.

Patient demographics are highlighted in Table 3. The mean (SD) age across the 21 patients was 56.5 (11.6), and 76.2% of them were women. Average (SD) pain duration was 4.7 (5.0) years, and the pre-procedural baseline VAS and WOMAC scores were 9.0 (1.2) and 68.1 (19.6), respectively. Procedural considerations relating to GRFA are detailed in Table 4. Most ablations

were performed either bilaterally (38.1%) or with left-side predominance in unilateral cases (38.1%). Mean (SD) procedural time for the ablation was 27.1 (13.3) minutes, and all cases were performed under moderate sedation. The Stryker SERFAS Energy Platform (Stryker Corporation) was the primary radiofrequency generator selected for genicular ablation (61.9%), with the Avanos RFA Solutions Generator System (Avanos Medical, Inc.) chosen for the remaining cases. Secondary diagnoses contributing to CK pain are listed in Table 5. Amongst the 21 patients, 81.0% met the BMI criteria for obesity, 66.7% were diagnosed with osteoarthritis, 47.6% had prior knee injuries, 14.3% were diagnosed with tendonitis and fibromyalgia, 9.5% were diagnosed with repetition and overuse injuries in addition to rheumatoid arthritis, and 4.8% were diagnosed with systemic lupus erythematous (SLE).

Effectiveness

Mean VAS scores for CK pain intensity had significantly decreased by 3.1 cm from a baseline score of 9.0 cm by the specified end (March 18th, 2025) (Table 6). Paired t-test analysis regarding both the completed case data set and computed data set revealed similar effects for the VAS scores that described CK pain intensity. Regardless of the data set or time between patients' receipt of the GRFA and the specified end, significant reductions in VAS scores were reported (*P*-value < 0.0001), indicating that patient withdrawal had an inconsequential impact on the results. Furthermore, by the specified end, 66.7% of the patients experienced a 20% or greater improvement in pain, 33.3% of patients experienced a 40% or greater improvement in pain, and 19.1% of patients experienced a 60% or greater improvement in pain (Fig. 3).

The paired t-test analysis of the WOMAC scores revealed significant improvements of a respective 32.4, 20.0, and 8.7 points at the one-, 3-, and 6-month follow-ups from a pre-procedure baseline score of 68.1 (*P*-value < 0.0001). At one month, 71.4% of the patients experienced a clinically significant improvement in their WOMAC scores, whether improvement was defined as a 16% or greater total score reduction from baseline or as a 20% or greater improvement in

Table 1. *Patient cohorts.*

	Number of Patients
Ablated	34
One-month follow-up	21
3-month follow-up	21
6-month follow-up	19
Completed study	21
Study withdrawals	13

Table 2. *Study withdrawal reasons (n = 13).*

- Patient withdrew consent: 5
- Patient was deceased: 4
- Lost to follow-up: 2
- Determined to be ineligible for participation: 2

Table 3. *Patient demographics and baseline characteristics (n = 21).*

Age (in years), mean (SD)	56.5 (11.6)
Female, n (%)	16 (76.2%)
Body Mass Index (BMI), mean (SD)	41.6 (11.8)
Pain duration (in years), mean (SD)	4.7 (5.0)
Visual analog scale (VAS) score for CK pain, mean (SD)	9.0 (1.2)
Western Ontario and McMaster Universities Arthritis Index (WOMAC) score, mean (SD)	68.1 (19.6)

Table 4. *Procedural characteristics (n = 21).*

Bilateral, n (%)	8 (38.1%)
Left side, n (%)	8 (38.1%)
Procedural time (in minutes), mean (SD)	27.1 (13.3)
Anesthesia type - Moderate sedation, n (%)	21 (100%)
Radiofrequency ablation generators and probes - Stryker SERFAS Energy Platform (Stryker Corporation) - Avanos RFA Solutions Generator System (Avanos Medical, Inc.)	 13 (61.9%) 8 (38.1%)
Length of hospital stay in days, mean (SD)	0
Procedure-related serious adverse events, n (%)	0
Intra- and post-procedural complications, n (%)	0

Table 5. *Secondary diagnoses (n = 21).*

Obesity, n (%)	17 (81.0%)
Osteoarthritis, n (%)	14 (66.7%)
Prior knee injuries, n (%)	10 (47.6%)
Tendonitis, n (%)	3 (14.3%)
Fibromyalgia, n (%)	3 (14.3%)
Repetition and overuse, n (%)	2 (9.5%)
Rheumatoid arthritis, n (%)	2 (9.5%)
Systemic lupus erythematous, n (%)	one (4.8%)

pain and physical function from baseline (Table 7). Improvement rates remained steady at 66.7% and 71.4%, respectively, for patients experiencing ≥ 16% total score reduction and ≥ 20% improvement in pain and physical function at the 3-month follow-up. However, the improvement rates, by both measures of clinical significance, declined to 42.1% for patients who had reached the 6-month mark.

As for the WOMAC categories (Table 8), most patients (66.7%) were classified as severely disabled before the procedure. By 6 months, though, only slightly over one-third (36.8%) of the patients were still classified as severely disabled, with the remaining 63.2% were mostly classified as either moderately or mildly disabled, demonstrating a significant recovery in physical function and stiffness after treatment. Notably, at the one- and 3-month follow-ups, around one-quarter (28.6% and 23.8%, respectively) of the patients experienced mild disability, while only a respective 9.5% and 14.3% of patients experienced severe disability, exemplifying remarkable improvement in function and stiffness after treatment. Considering the findings described at 6 months, however, there appears to be a transient period of tremendous improvement after the ablation, followed by a moderate reduction, suggesting a decline in effectiveness that is overall still an improvement from baseline.

Table 6. *VAS outcomes*.

Outcome	Specified End (n = 21) (×)
Mean improvement from baseline, mean (SD)	3.1 (2.6)*
Mean percentage improvement from baseline, mean (SD)	33.9% (28.9)
> 0% improvement, n (%)	17 (81.0%)
≥ 20% improvement, n (%)	14 (66.7%)
≥ 40% improvement, n (%)	7 (33.3%)
≥ 60% improvement, n (%)	4 (19.1%)

×The specified end was March 18th, 2025, to establish uniformity when measuring VAS outcomes across time.
*Denotes statistical significance, *P*-value < 0.0001.

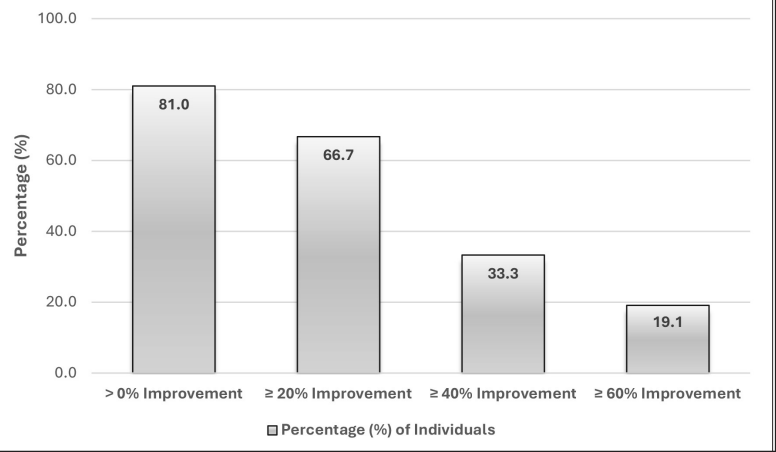


Fig. 3. *Bar graph of VAS score reduction from baseline pain at the specified end (March 18th, 2025). Each bar represents a percentile's improvement in VAS score, with the number above representing the percentage of individuals who met the corresponding percentile improvement.*

Safety

Zero (0) procedure-related adverse events or intra- or post-procedural complications occurred during the investigation (Table 4). Across the 34 ablations, the overall adverse event rate was 0%, with every patient discharged on the day of undergoing the procedure. Patients responding to the quality of improvement survey (n = 21) after the completion of the study reported mild to moderate improvements in sleep, fatigue, anxiety, and depression after treatment in 42.9% of cases; in 14.3% of cases, patients reported profound improvements in all 4 of those quality metrics. Patients were also assessed on the Quality of Life subsection of the KOOS, with the mean score (SD) reported as 34.2 (28.5), suggesting moderate to severe difficulty with, constant awareness of, and low to medium confidence in the affected knee(s). Together, the quality of improvement survey and Quality of Life subsection suggest a disconnect between patients' apparent psychological and mental improvement after receiving ablations and their delayed trust and belief in the physical mechanisms of their knees.

Discussion

The present study investigated the effectiveness and safety of the GRFA as a treatment option for patients suffering from CK pain. Over the course of 6 months, a patient population that satisfied the relevant criteria and responded to GRFA for CK pain was followed and studied. On average, the patients demonstrated a 3.1-cm reduction in their VAS scores from the baseline values. This reduction reflects a mean

improvement of 33.9% (Table 6), which indicates a clinically significant reduction in the intensity of knee pain. Furthermore, patients' functional outcomes improved following genicular ablation, as WOMAC scores showed clinically significant improvements in 71.4%, 66.7%, and 42.1% of the patients at the end of one, 3, and 6 months after the procedure, respectively (Table 7). Importantly, zero (0) procedure-related, intraoperative, or postoperative complications were observed, and every patient was discharged home on the same day that the procedure occurred. Together, these findings reflect the effectiveness and safety profile of GRFA and highlight its potential as a minimally invasive treatment modality for reducing pain and improving functional outcomes in patients with CK pain.

Table 7. *WOMAC outcomes*.

Outcome	1 Month (n = 21)	3 Months (n = 21)	6 Months (n = 19)
Clinically significant improvement (†), n (%)	15 (71.4%)	14 (66.7%)	8 (42.1%)
Clinically significant improvement (‡), n (%)	15 (71.4%)	15 (71.4%)	8 (42.1%)
Mean improvement from baseline, mean (SD)	32.4 (25.3)*	20.0 (22.9)*	8.7 (27.4)*

†Defined as a ≥16% reduction in total score compared to baseline.
‡Defined as a ≥ 20% improvement in pain and physical function from baseline.
*Denotes statistical significance, *P*-value < 0.0001.

Table 8. *WOMAC categories*.

Category	Pre-Procedure (n = 21)	1 Month (n = 21)	3 Months (n = 21)	6 Months (n = 19)
No disability, n (%)	0	2 (9.5%)	0	one (5.3%)
Mild disability, n (%)	one (4.8%)	6 (28.6%)	5 (23.8%)	2 (10.5%)
Moderate disability, n (%)	6 (28.6%)	11 (52.4%)	13 (61.9%)	9 (47.4%)
Severe disability, n (%)	14 (66.7%)	2 (9.5%)	3 (14.3%)	7 (36.8%)

Since Choi et al's introduction of GRFA in 2011, there has been a growing body of evidence supporting its use as a form of CK pain management (16). Subsequent studies from Shi et al have demonstrated that GRFA is safe and effective in treating knee osteoarthritis, persistent pain after total knee arthroplasty, and pain localized in the inferolateral quadrant of the knee (9,13). Additionally, various randomized controlled trials have further shown that reductions in VAS scores at one, 3, and 6 months after GRFA are more significant than those that appear after placebo procedures, again reinforcing the role of GRFA in treating osteoarthritis and CK pain (16). Similarly, other retrospective studies have reported improvements in both WOMAC and VAS scores, along with decreased reliance on analgesic medication, following GRFA treatment (17).

The outcomes of the current study support and align with the findings in existing literature. Previous research has shown that GRFA can lead to functional improvements, as measured by WOMAC scores, within the first 6 months following the procedure (18). Our study mirrors these findings, as 42.1% of patients experienced a clinically significant improvement in their WOMAC scores within the first 6 months after ablation. Importantly, the observed attenuation in functional improvements over time should not be interpreted as a failure of the procedure. Instead, the return reflects the expected peripheral nerve regeneration that follows the ablation. The peripheral nerves in the human body are known to regenerate at a rate of one mm per day, making the functional recurrence of pain over several months a physiologically anticipated phenomenon (19). Because this renewal of pain is expected, it can therefore be managed clinically, as GRFA can be repeated safely and effectively as symptoms recur. This observation highlights one of the major functional benefits of GRFA when compared to alternative management strategies.

GRFA offers several distinct advantages over other therapeutic options for managing CK pain. One popular treatment option for CK pain includes intra-articular corticosteroid injections, which have been used widely. These injections deliver steroids, such as methylprednisone or triamcinolone, directly into a joint and have been shown to provide short-term symptom relief to patients with rheumatoid arthritis and osteoarthritis (20). However, the duration of relief experienced after a corticosteroid injection has been shown to vary individually and often decreases on repeated administration. Furthermore, while intra-articular corticosteroids decrease pain, randomized controlled studies have not shown consistent or sustained improvement in actual functional outcomes (21). In addition to these limitations, corticosteroid injections are also associated with various adverse effects, including arthralgia, headache, and back pain (22). Moreover, repeated injections have resulted in a more accelerated loss of cartilage thickness than is associated with placebo saline injections (7). Therefore, current clinical guidelines for intra-artic-

ular corticosteroid injections recommend that patients undergo no more than 4 such injections per year (7).

In contrast to the corticosteroid injections, the results observed in this present study demonstrate a clinically significant improvement in both pain and functional outcomes among patients who underwent GRFA. As mentioned previously, patients on average experienced a mean reduction of 3.1 cm in VAS pain scores, corresponding to a 33.9% improvement from baseline, and 66.7% of patients achieved at least a 20% reduction in pain intensity. Functional outcomes, assessed using the WOMAC scores, also showed clinically significant improvements at one, 3, and 6 months post-ablation. These results support the notion that GRFA is associated with a sustained benefit beyond the short-term relief that corticosteroid injections offer. Notably, unlike that type of injection, GRFA is safely repeatable as symptoms recur, showing no evidence of joint damage or systemic adverse effects, highlighting another major advantage over repeated corticosteroid injections. Collectively, these results illustrate the growing role of GRFA and why it should be considered a viable, effective alternative to intra-articular corticosteroid injections.

Intra-articular hyaluronic (HA) injections are another widely accepted form of treatment for CK pain. These injections deliver exogenous hyaluronic acid, a major component of synovial fluid and articular cartilage, into the affected knee joint. This technique helps maintain joint homeostasis and protects the remaining cartilage from degradation by interacting with both matrix metalloproteases and various inflammatory pain mediators. The use of intraarticular HA injections gained popularity after multiple clinical trials that demonstrated improvement in both functional activity and pain management in patients with osteoarthritis-related knee pain (23). Although HA injections can result in those benefits, the analgesic and functional effects of the procedure are typically delayed and require up to 4 weeks for patients to notice the initial pain relief. The analgesic benefits then peak at approximately 8 weeks and attenuate at around 24 weeks. Additionally, achieving meaningful pain relief often requires multi-injection regimens, and repeated HA injections have been associated with an increased incidence of local inflammatory reactions, including knee synovitis (24,25). Taken together, these limitations reduce the benefit and practicality of HA injections for patients seeking rapid or sustained pain relief.

Conversely, this investigation exemplifies the immediate improvements in both pain and function that GRFA provides without the need for repeated treatment sessions. Besides the clinically significant reduction in their VAS scores, most patients also experienced profound early improvements in their WOMAC scores. This study additionally illustrated a sustained reduction in disability severity at 6 months, with the proportion of patients classified as severely disabled decreasing by nearly half when compared to the pre-procedure cohort. Importantly, across 34 ablations, there were no adverse events related to the procedure or complications in the intraoperative or postoperative stages of treatment. Moreover, every patient was able to be discharged home on the same day that the procedure occurred. All together, these findings emphasize the safety profile of GRFA and highlight its potential to offer a more rapid onset of analgesia and durable improvements in functional status than intra-articular HA injections can.

The definitive surgical treatment for refractory CK pain is TKA or total knee replacement. TKA is one of the most frequently performed orthopedic procedures worldwide and aims to correct joint deformities, reduce pain, and improve patients' overall quality of life (26). Despite the effectiveness of TKA, a variety of factors influence both patients' and surgeons' decisions about whether and when to undergo the procedure. TKA is associated with a substantial perioperative and recovery burden, including prolonged operative time, inpatient hospitalizations, and extended rehabilitation, and the risk of perioperative complications is always a factor. Nevertheless, TKA is also associated with excellent long-term outcomes, with patient satisfaction rates ranging from 80-100%, reinforcing the role of TKA as the cornerstone intervention for end-stage knee pain (27).

While GRFA may not serve as a direct substitute for TKA, the findings in this study support the former's role as a helpful bridge to delay the need for the latter, as well as in providing symptomatic relief to patients deemed poor candidates for surgery. In contrast to the prolonged hospital stays and preoperative burden associated with TKA, GRFA was performed amongst this cohort under moderate sedation and had a mean procedural time of 27.1 minutes, with all patients discharged home on the day of the procedure and no preoperative-related adverse events recorded. Additionally, TKA has a variety of contraindications and often requires patients to lose weight prior to the operation. Many patients are unable to meet the surgical

criteria for consideration and may overall be poor surgical candidates, thereby restricting their access to TKA. Meanwhile, GRFA has a minimally invasive nature, few contraindications, and a low level of perioperative risk, highlighting the procedural ease and feasibility of the treatment. Collectively, these observations suggest that GRFA serves an important role within the treatment algorithm for CK pain, offering immediate pain relief and functional improvement with little procedural burden in appropriately selected patients.

GRFA not only provides clinical effectiveness but also offers advantages in patient tolerability, procedural efficiency, and health care utilization. The population of patients who experience CK pain often includes older adults or those with significant comorbidities that limit tolerance for invasive interventions or prolonged recovery periods. The minimally invasive nature of the GRFA therefore makes it increasingly favorable when considering the population likeliest to need interventions for CK pain. The mean procedural duration in this investigation was noted to be approximately 30 minutes, with all patients discharged home on the day of the operation without complication. This result is the opposite of what is seen with surgical interventions like TKA, which is associated with prolonged operative times, inpatient hospitalizations, and extended rehabilitation.

GRFA induces pain relief through targeted thermal lesioning of the sensory genicular nerve branches responsible for transmitting nociceptive signals from the anterior knee capsule. This mechanism allows for the preservation of surrounding motor fibers, which reduces pain signals while still maintaining functional stability (14). As discussed previously, the genicular nerve regenerates over time, as expected, and the recurrence of pain should also be anticipated rather than interpreted as a procedural failure. Because of this nerve regeneration, GRFA can be repeated safely when symptoms recur, without evidence of nerve injury, joint degeneration, and repeat procedures continue to provide statistically significant pain relief, although the response may be less robust than that observed after the initial treatment. (28). This phenomenon again differs from those associated with other interventions like corticosteroid injections, which cannot be repeated with such ease because their risk profiles increase with each attempt. The simplicity, quick recovery, and ability for repeat treatment support GRFA as an appropriate, strong option for the management of CK pain.

As the use of GRFA continues to grow, the discussion regarding appropriate device and instrument selection will naturally grow as well. Multiple radiofrequency devices are currently available, with some of the most popular devices namely created by entities like the Stryker Corporation and Avanos Medical, Inc. These systems differ in lesion size capability, probe geometry, temperature control mechanisms, and energy delivery profiles. The Avanos RFA Solutions Generator System (Avanos Medical, Inc.) possesses the ability to engage a cooling technique that minimizes overheating and charring surrounding tissue, though the option was not utilized in this study. Meanwhile, the MultiGen® 2 Radiofrequency Generator (Stryker Corporation) leverages a higher-power, more advanced probe to better encapsulate and burn a particular nerve target. These distinctions will impact operator preference, workflow efficiency, and lesion consistency, especially when the anatomical variability across patients is considered. Although radiofrequency generators have several differences in their designs, current evidence suggests that the clinical outcomes of radiofrequency are driven mainly by accurate anatomical targeting and procedural technique, rather than the use of specific devices (14).

Device selection is thus most likely chosen based on clinician preference and availability. As the demand for minimally invasive therapies continues to increase and the use of GRFA expands, future studies might review the cost-effectiveness of different devices to help elucidate the most optimal and economical ablation technique for patients. The ensuing data would be particularly instrumental for addressing insurance coverage limitations and payer hesitancy.

Limitations

A few limitations of this study should be acknowledged while interpreting the results. The study was retrospective, which could have introduced the possibility of selection and information bias. This study also had a single-center setting and was performed with a relatively small sample size, which might have limited the generalizability of the results; additionally, patients lost to follow-up over time decreased the number of individuals whose long-term outcomes could be assessed, specifically at the 6-month interval, thereby limiting the certainty of treatment duration. Lastly, due to the ethical concerns of extending delays in patient care and increasing the time spent in pain—because of insurance company requirements, as described in the introduction—as well as the practical concerns of more greatly reducing the number of ablated patients

eligible for data analysis, no sham operation to determine a placebo response was conducted to further demonstrate the effectiveness of GRFAs. Therefore, the results of this study should be considered hypothesis generating rather than confirmatory. Despite these limitations, improvements in pain and function across follow-up periods remained consistent and supported the effectiveness and safety of GRFAs, aligning with the growing body of literature that corroborated and validated our findings, and vice versa.

Conclusions

In summary, the results of this study reinforce GRFA as a safe, effective, and minimally invasive treatment option for patients experiencing CK pain over a 6-month period. Due to its favorable safety profile, rapid recovery rate, and ability to preserve motor function, GRFA should be deemed a valuable option for patients who are either unresponsive to conservative therapies or considered poor surgical candidates. The replicability of GRFAs in the setting of expected nerve regeneration further enhances their use for chronic disease management. Future research is critical and should focus on longer follow-up durations, prospective randomized trials, device-specific outcomes, and comparisons with traditional CK pain interventions. As insurance coverage continues to be a significant barrier to the widespread adoption and utilization of GRFA, further research as demonstrated here may help shift perceptions and cultivate the acceptance of the procedure as a legitimate therapy for patients with CK pain.

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